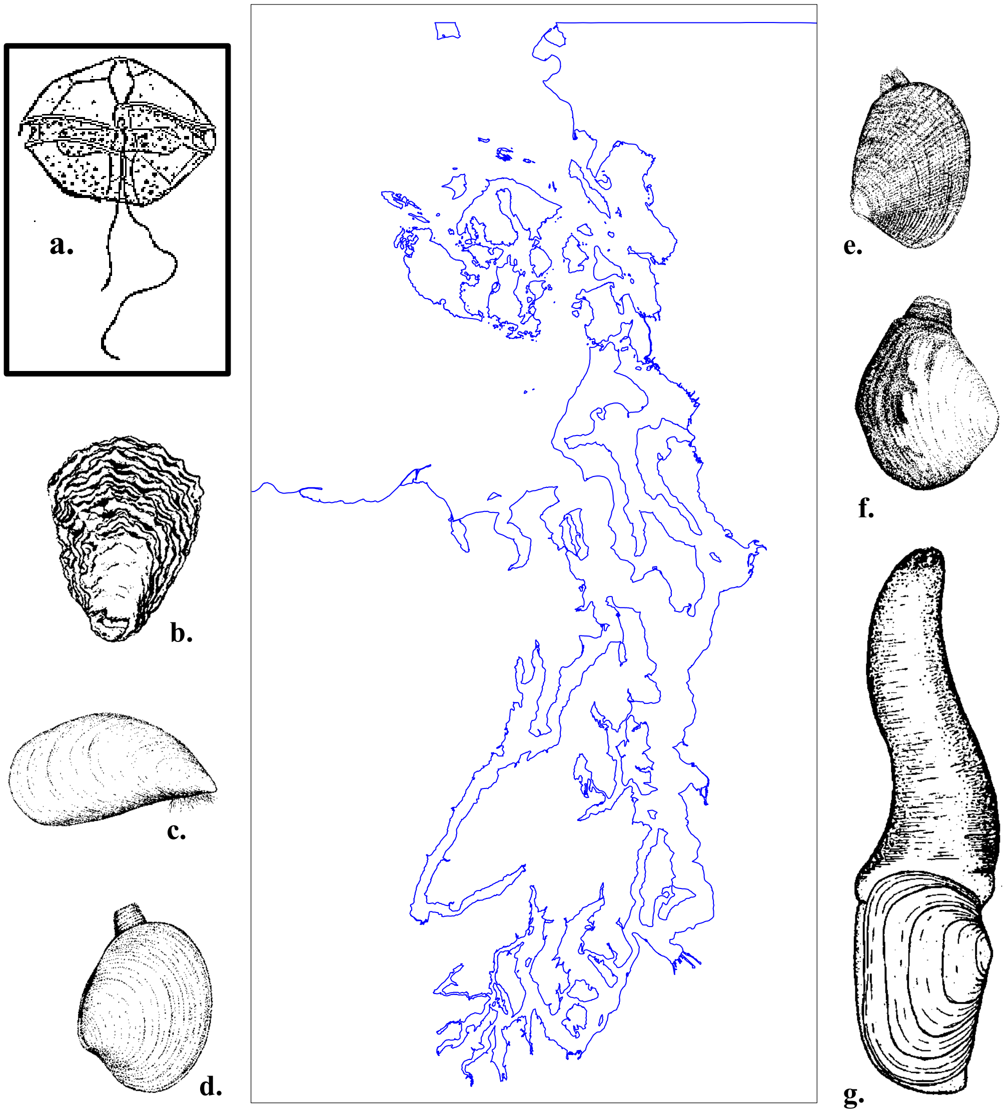
Paralytic Shellfish Poisoning (PSP) Patterns in Puget Sound Shellfish in 2001

A Report for the Puget Sound Ambient Monitoring Program



a. Alexandrium catenella **(source of PSP toxin)**

b. Oyster	e. Manila clam
c. mussel	f. horse clam
d. butter clam	g. geoduck

Washington State Department of Health

Office of Food Safety and Shellfish Programs

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Washington State Department of Health

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The Department of Health works to protect and improve the health of people in Washington State

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Acknowledgements

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Introduction

Mandate of the Washington State Department of Health
The Washington State Department of Health (DOH) monitors biotoxin levels in shellfish from sites throughout Western Washington to protect shellfish consumers from poisoning by naturally occurring biotoxins that if present can accumulate in shellfish tissue. When harmful levels of biotoxins are detected, DOH issues warnings to commercial shellfish growers, local health agencies, tribal resource agencies, and the public. Warnings are issued via newspapers, television, the Department of Health Biotoxin Hotline (1.800.562.5632), and by Internet (www.doh.wa.gov/ehp/sf/biotoxin.htm).

Puget Sound Ambient Monitoring Program
Washington State has monitored biotoxins in shellfish since the 1930s. Monitoring was greatly expanded by the early 1960s. At present, shellfish samples are analyzed for biotoxins from hundreds of sites throughout Puget Sound and on the coast. In 1990, DOH set up a Sentinel Monitoring Program to provide systematic early warning of harmful levels of biotoxins such as "paralytic shellfish poisoning" (PSP) in shellfish caused by blooms of toxic phytoplankton. Additionally, DOH reports spatial patterns and temporal trends in the data from the Sentinel stations to the Puget Sound Water Quality Action Team as a participating agency of the Puget Sound Ambient Monitoring Program (PSAMP). This year's report includes analysis from 34 Sentinel sites.

Background

PSP Toxin
A number of genera of marine phytoplankton produce an array of chemically similar neurotoxins responsible for PSP (Boczar et al., 1988). Neurotoxins are so-named because they disrupt nerve impulses. These toxins act together to produce PSP. Symptoms may progress from numbness and tingling of lips, and loss of muscular coordination, to respiratory arrest and, ultimately, death. There is no known antidote. In extreme cases, survival depends on immediate availability of life-support systems. Death results in about 15 percent of cases worldwide (Nishitani et al., 1994). The U.S. Food and Drug Administration has set an action level for PSP at no more than 80 μg of PSP toxin in 100 g of shellfish tissue. When the level of PSP in a single sample of a particular shellfish species exceeds the action level, DOH closes commercial and recreational harvest areas for that species. The areas are reopened only when continued monitoring assures a return to safe conditions.

Bivalve shellfish concentrate biotoxins when they filter toxic phytoplankton out of the water while feeding. The shellfish do not appear to be affected by the toxin. PSP toxin accumulates in marine animals that feed either directly on toxic phytoplankton or on consumers of toxic phytoplankton. These consumers include zooplankton, bivalve shellfish (oysters, mussels, clams, etc.), predatory marine snails (moon snails and whelks), crabs, fish, birds and marine mammals (Matter, 1994). Mass mortalities among other shellfish-eating animals, including birds, fur seals, foxes, sea otters (Kvitek and Beitler, 1988), and humpback whales have been traced to PSP (Geraci et al., 1989). People are poisoned when they eat shellfish or other marine life that contain excessive levels of PSP toxin.

Phytoplankton Ecology and Biotoxins

Phytoplankton are one-celled marine plants that can conduct *photosynthesis*. Photosynthesis enables plants to use the energy of the sun to make food from carbon dioxide and nutrients taken from the water. Oxygen is produced as a by-product. Phytoplankton and other photosynthesizers are the basic source of energy for all components of the marine food web.

During wintertime rain storms, rivers and stormwater runoff carry nutrients into Puget Sound from nearby uplands and watersheds. Strong winds mix the freshwater with nutrient-rich water coming in from the open sea. The dim sunlight limits growth. Phytoplankton is continually cycled from the surface to the dimly lit depths and back up again, awaiting the arrival of favorable conditions for growth.

In early spring, strong winds subside, and the sun warms the water's surface. The water column stabilizes and vertical mixing stops. A second influx of nutrients occurs when summer snowmelt increases flow of the major Puget Sound rivers. The abundant dissolved nutrients in a stable water column lead to blooms of many phytoplankton species in sunlit surface waters. Blooms can be so dense that the phytoplankton colors the water. The condition is sometimes called a *red tide*. However, the term is misleading because the colors (produced by photosynthetic pigments) may range from brown to orange to purple. Blooms are sometimes associated with a group of phytoplankton termed *dinoflagellates*. About 60 dinoflagellate species (of over 2,000) produce biotoxins. *Alexandrium catenella,* which causes PSP in Puget Sound, is a dinoflagellate (see picture on front cover). It is important to note that PSP may reach dangerous levels in shellfish long before the density of *Alexandrium catenella* becomes numerous enough to discolor the water.

Two whip-like *flagella* enable dinoflagellates to move vertically in the water column. By mid to late summer, surface waters are frequently depleted of nutrients and many species of phytoplankton die back. But dinoflagellates journey to deeper water where nutrients remain plentiful. They return to the sunlit surface to carry on photosynthesis. Vertical migration may give dinoflagellates an advantage over other phytoplankton species. As a result, dinoflagellate blooms often extend into late autumn. By that time, falling water temperatures and the onset of wind-induced vertical mixing lead to a breakdown of the stratification of the water column, and sunlight becomes too dim to continue production. Under these conditions dinoflagellates, such as *Alexandrium catenella*, may form resting cysts that settle to the bottom to await the return of favorable growth conditions (Anderson 1980). A resting cyst may be ten times more toxic than its free-swimming form (Dale et al., 1978).

PSP History in the Northwest

In June 1793, four crewmen with Captain Vancouver's expedition became sick and one died shortly after eating shellfish along the central coast of British Columbia (Strickland 1983). Several PSP-related deaths occurred on the Washington coast in 1942. The causative agent for PSP was first tentatively identified as the dinoflagellate *Gonyaulax catenella* (now known as *Alexandrium catenella*) during an outbreak in northern Strait of Georgia in 1965 (Strickland 1983).

By the 1970s, closures caused by PSP toxicity occurred in the San Juan Islands and Bellingham (for locations see Figure 1). In September 1978, heavy rains followed by a late-summer warm period produced highly toxic blooms (Strickland 1983). The 1978 bloom produced PSP illnesses from Saratoga Passage to Vashon Island.

In 1987, PSP went above the FDA Action level in Hood Canal as far south as Stavis Bay (near Seabeck) for the first time since DOH sampling began. In 1988, PSP levels exceeding the U.S. FDA action level were detected in shellfish from Fox Island and Minter Bay in South Puget Sound. In the mid-1990s, a moderate bloom occurred at several points in South Puget Sound. A very intensive and widely distributed bloom occurred there in late 1997 (Determan 1999).

Sampling and Analytical Methods

DOH maintains two biotoxin monitoring programs. A larger general program monitors biotoxin in numerous species of clams and oysters collected from hundreds of locations throughout Puget Sound. A second highly structured *Sentinel Monitoring Program* provides early warning of the onset of PSP activity. The Sentinel Monitoring Program helps guide regional monitoring under the larger general program. The program was designed by Nishitani, (1990). A single species is sampled at about 40 fixed points through Washington's marine waters. The species sampled is generally the blue mussel, *Mytilus edulis*. However, *M. galloprovincialis* (possibly a subspecies of *M. edulis*) and *M. californianus* are sampled at a few Puget Sound sites. At most sites, wire mesh cages (40cm x 40cm x 20cm; 2.5cm mesh size) are periodically stocked with mussels. The cages are then suspended about one meter deep below floats and docks, and sampled every two weeks year-round. At a few sites, natural-set mussels are scraped from floats, pilings and rocks. Seventy to 100 average-sized mussels (1-2 inches in length) provide 100 grams of tissue for analysis. The mussels are put into one-gallon "ziplock" bags, chilled with frozen gel packs, and shipped to the DOH Laboratory in Seattle, where they are analyzed using the mouse bioassay (APHA 1984).

Results and Discussion

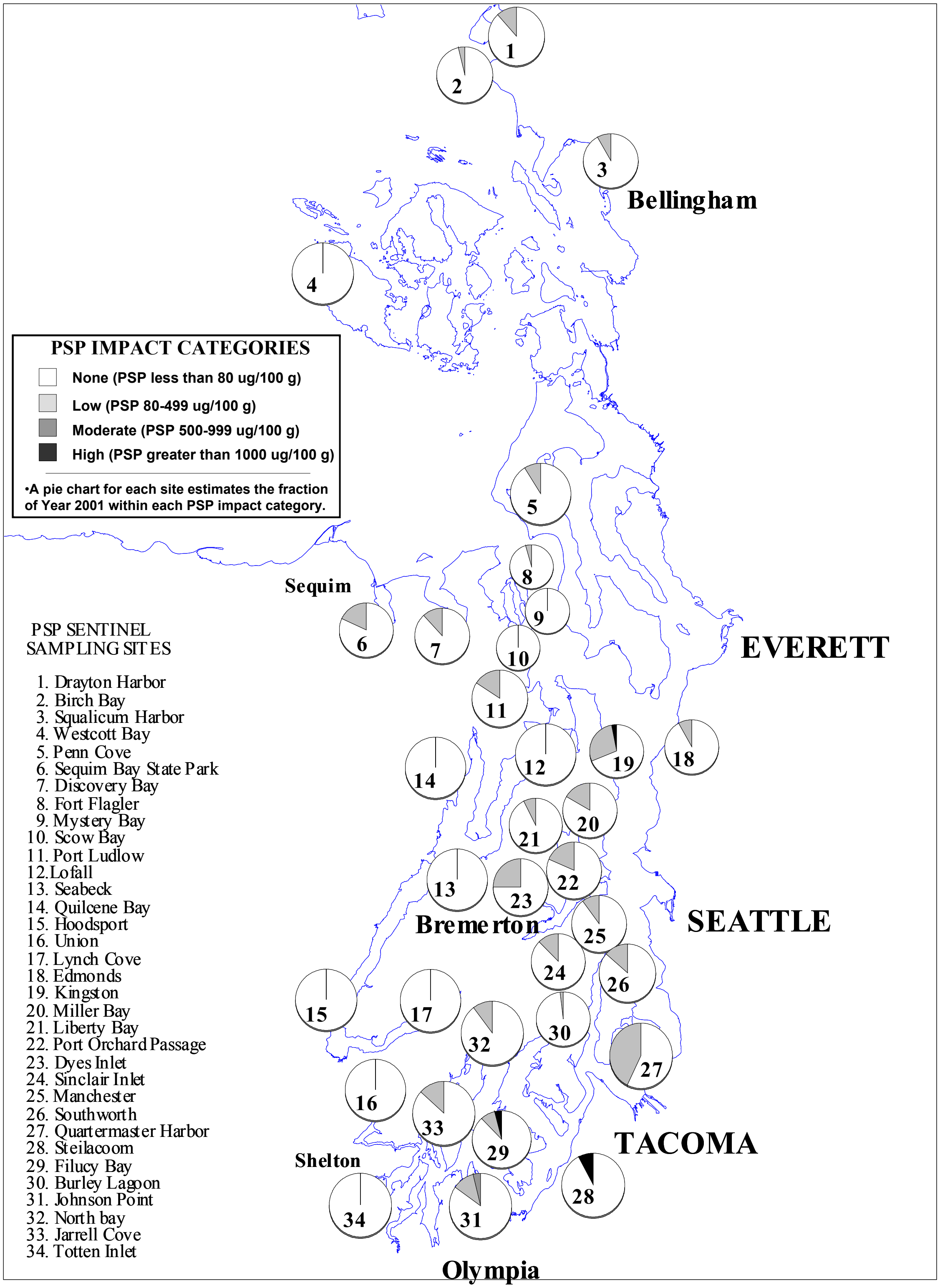
Spatial Distribution of PSP in the Year 2001

PSP results from 34 of the 40 Sentinel sites in calendar year 2001 were sorted into four categories based on PSP impact. These **PSP Impact Categories** are as follows:

None: PSP level was less than 80 µg per 100 grams of shellfish tissue (FDA action level);
Low: PSP level ranged from 80-499 µg per 100 grams of shellfish tissue;
Moderate: PSP level ranged from 500-999 µg per 100 grams of shellfish tissue;
High: PSP level was greater than 1000 µg per 100 grams of shellfish tissue.

The proportion of PSP results falling within each PSP category is shown as a pie chart for each Sentinel site in Figure 1. The greatest impact occurred at three sites in South Puget Sound and Kingston in the Main Basin. Hood Canal south of Lofall, Totten Inlet in South Puget Sound, and Westcott Bay on San Juan Island were free of PSP in 2001.

Figure 1. Spatial distribution of PSP impact in Puget Sound during Year 2001.



Ranking of PSP Sites According to PSP Impact in the Year 2001

Figure 1 indicates that 24 of the 34 Sentinel sites examined had a measure of PSP impact (i.e., **Low-High**) during 2001. These sites were ranked by calculating annual PSP impact as follows:

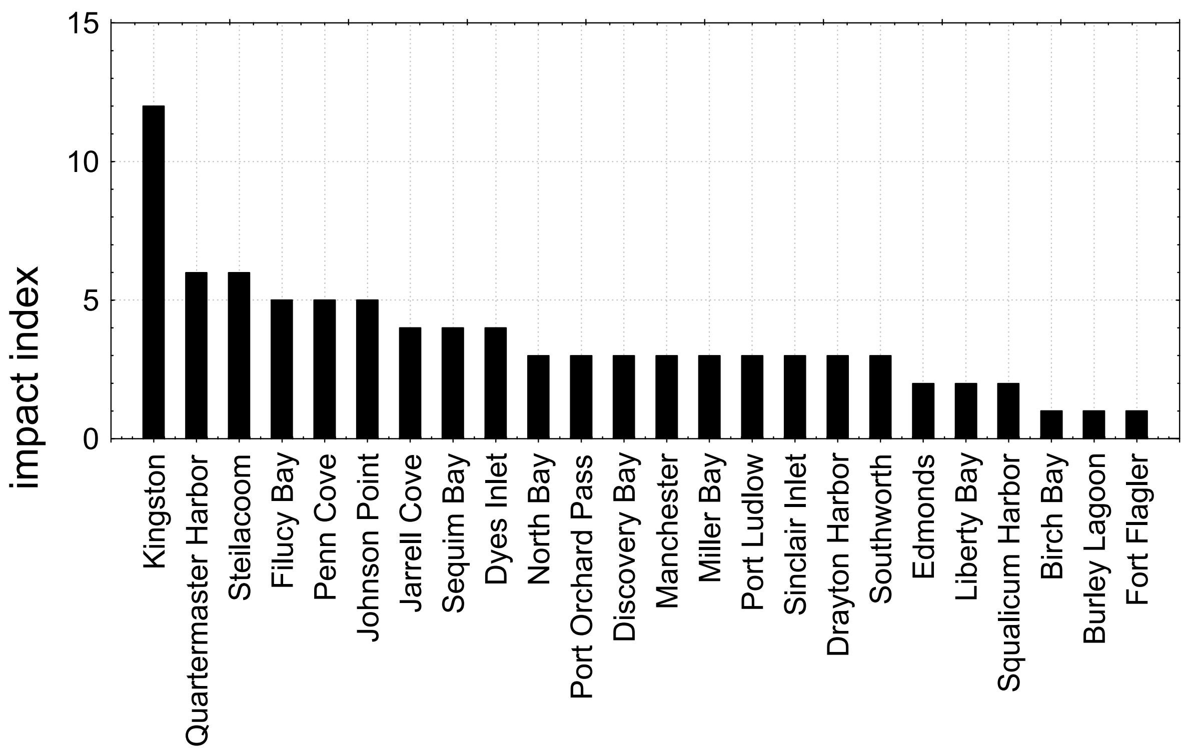
$$\textit{PSP IMPACT FACTOR} = (T_{LOW})(wf_{LOW})+(T_{MOD})(wf_{MOD})+(T_{HIGH})(wf_{HIGH})$$

Where:

T_{LOW} = number of PSP results in LOW category;
wf_{LOW} = "weighing factor" for LOW PSP results=1;
T_{MOD} = number of PSP results in MODERATE category;
wf_{MOD} = "weighing factor" for MODERATE PSP results =2;
T_{HIGH} = number of PSP results in HIGH category;
wf_{HIGH} = "weighing factor" for HIGH PSP results (=3).

The impact factors for each Sentinel site are shown in Figure 2. The highest PSP impact occurred at Kingston. Quartermaster Harbor in the Main Basin and two South Puget Sound sites (Steilacoom and Filucy Bay) followed. Significant impact occurred at Penn Cove for the first time since 1978.

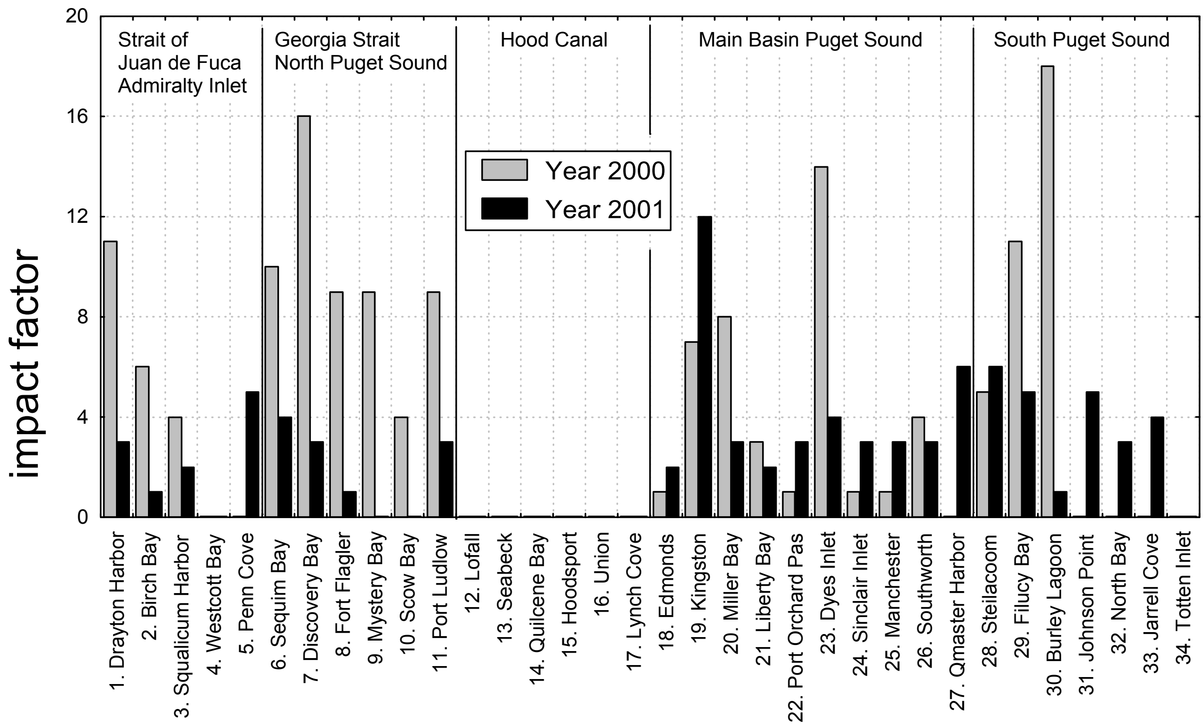
Figure 2. Ranking of PSP-impacted Sentinel sites in Puget Sound during the year 2001



Comparison of PSP impact in 2000 and 2001

Figure 3 compares PSP impact in 2000 and 2001 at the 34 DOH Sentinel sites. Nine of 10 Sentinel sites in North Puget Sound and the straits of Georgia and Juan de Fuca showed reduced PSP impact in calendar year 2001. On the other hand six of 11 sites in the Main Basin and four of 7 sites in South Puget Sound had greater PSP impact in 2001. Over all 11 sites were higher in 2001 than in 2000, and 15 were lower. Eight sites (six in Hood Canal) had no PSP activity.

Figure 3. Comparison of PSP Impact at PSP Sentinel sites in 2000 and 2001.



Annual PSP Duration

Annual PSP duration is the estimated number of days in a year when PSP levels exceed the FDA action level (80 µg per 100 g tissue). Annual PSP Duration is used solely for reporting status and trends in PSP for the Puget Sound Ambient Monitoring Program. DOH does not use it to manage PSP closures. The protection of shellfish consumers requires analysis of PSP data from samples of many shellfish species taken from many different growing areas throughout Puget Sound. Considerable professional judgment is exercised.

Figure 4 shows annual PSP duration (number of days) for selected PSP sites in Puget Sound for the years from 1991-2000. The number before the name of each site indicates its location as shown in Figure 1. “No data” means sampling had not yet started (e.g., 3. Squalicum Harbor prior to 1999) or there was a break in sampling (e.g. 30. Burley Lagoon 1993-1998). “No PSP” means PSP was not detected that year (e.g., Birch Bay 1995 and 1998).

The graphs of Quartermaster Harbor and North Bay show that they have been generally high in the past, but comparatively little PSP activity occurred in 2001. Generally speaking, there appears to be little temporal pattern present.

Conclusions

- PSP episodes are currently unpredictable in time or space due to the interaction of many poorly understood environmental factors.

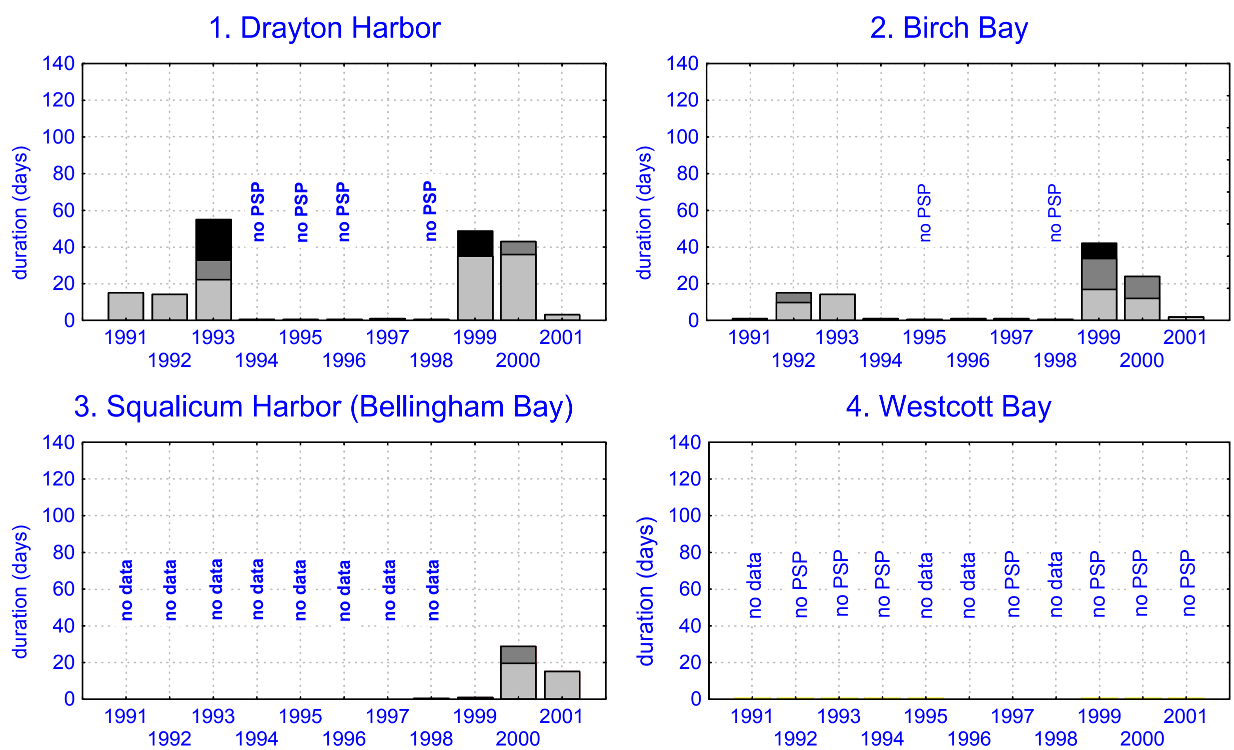
- Protection of shellfish consumers from poisoning by biotoxins will require continued routine comprehensive monitoring throughout Puget Sound.

Figure 4. Annual PSP Duration at selected sites in Puget Sound 1991-2000 (the following legend applies to three categories of PSP impact shown).

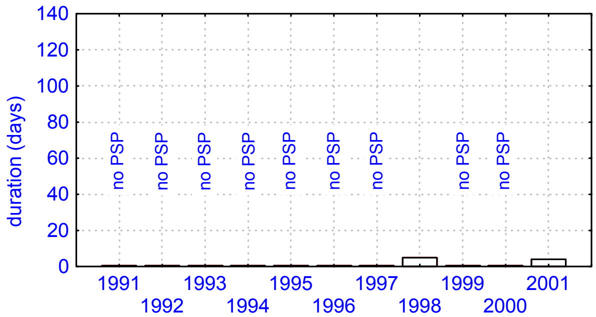
PSP DURATION

- Low (PSP 80-499 ug/100 g)
- Moderate (PSP 500-999 ug/100 g)
- High (PSP greater than 1000 ug/100 g)

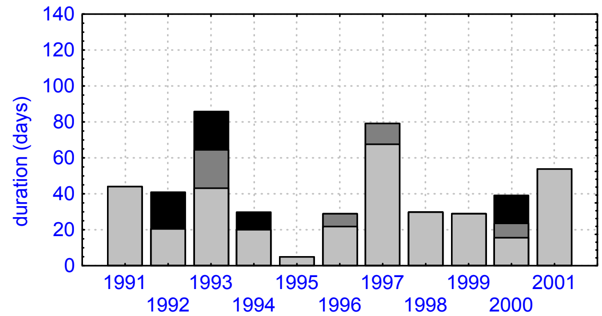
Bar graphs estimate the duration (number of days) of each year (1991-2000) when PSP likely was in each category.



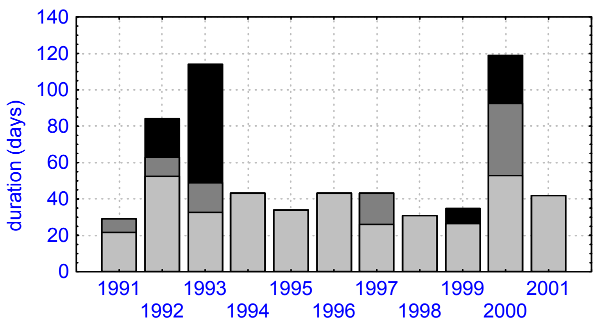
5. Penn Cove



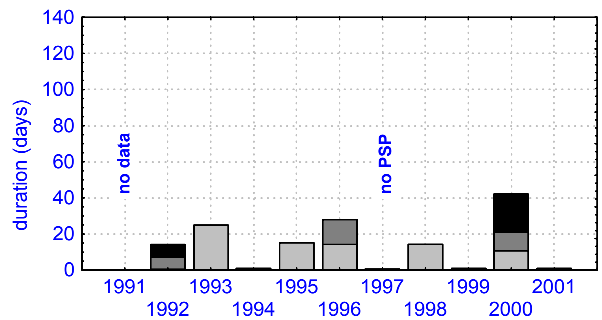
6. Sequim Bay



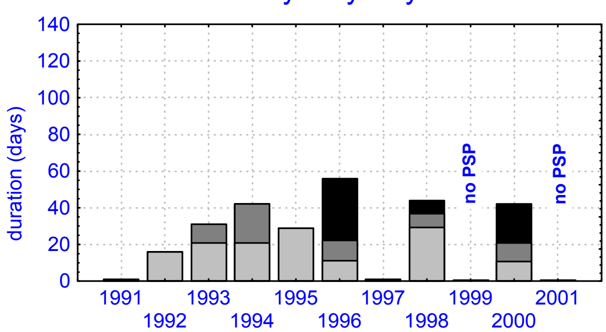
7. Discovery Bay



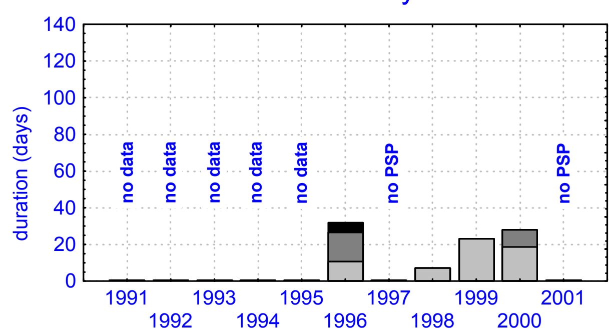
8. Fort Flagler



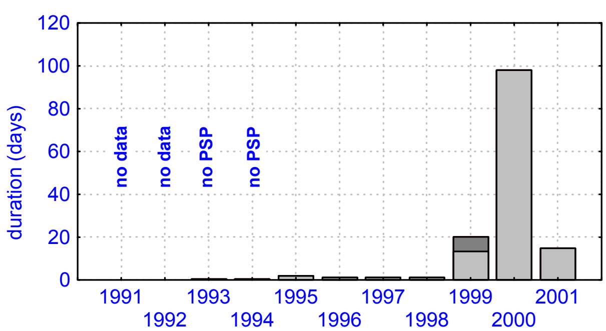
9. Mystery Bay



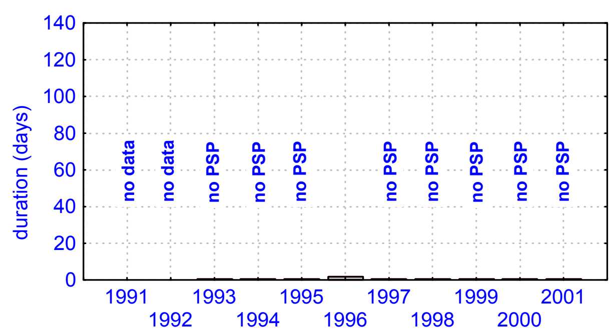
10. Scow Bay



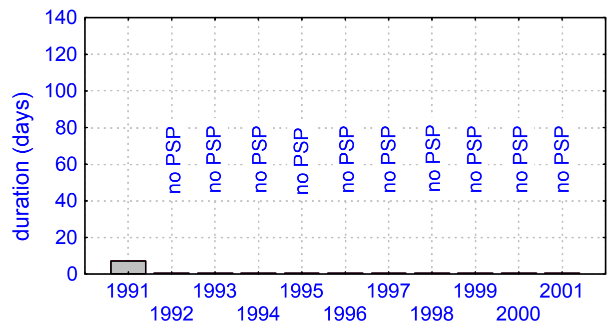
11. Port Ludlow



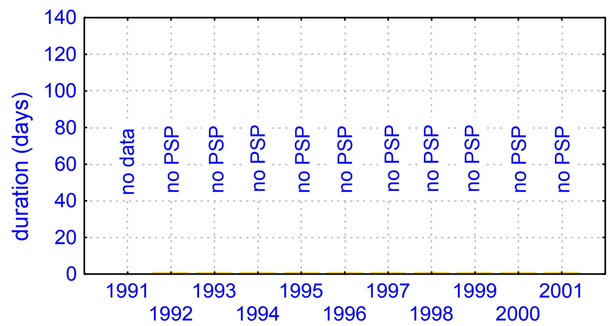
12. Lofall



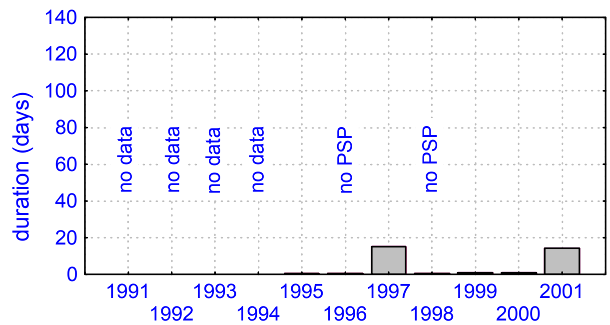
13. Seabeck



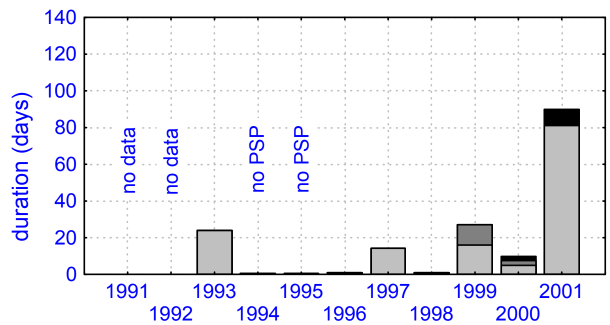
14-17. Hood Canal sites



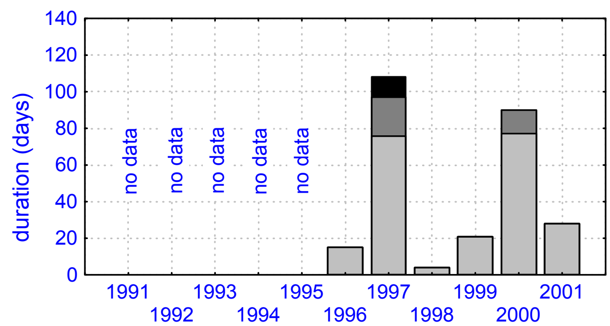
18. Edmonds



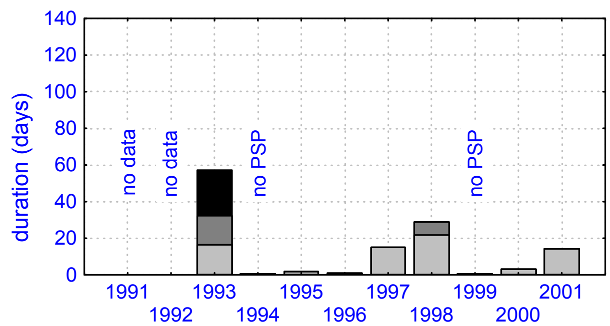
19. Kingston



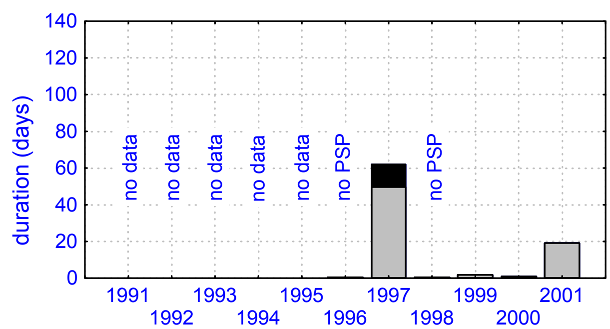
20. Miller Bay



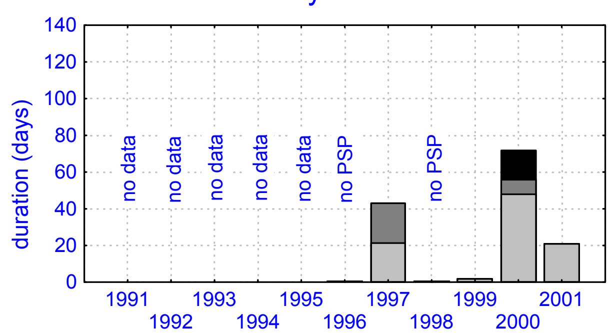
21. Liberty Bay



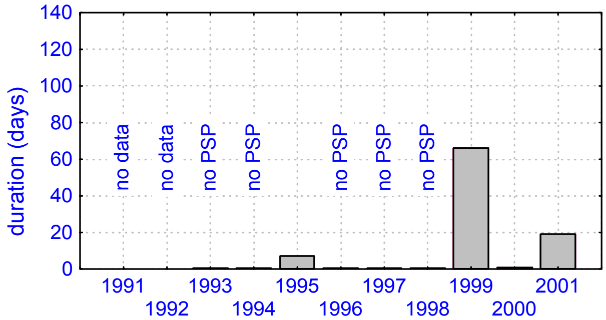
22. Port Orchard Pass



23. Dyes Inlet



24. Sinclair Inlet



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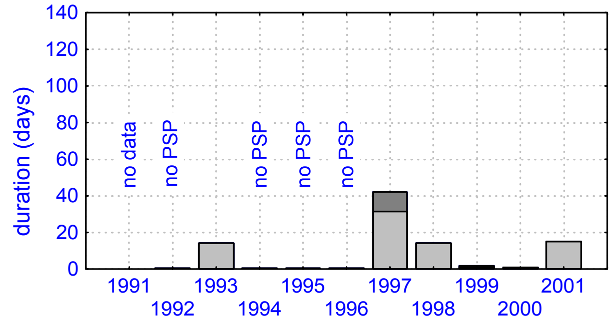
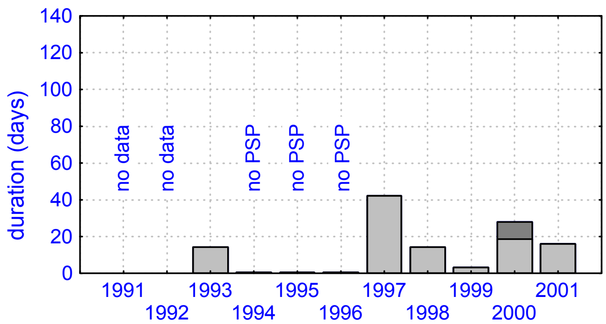
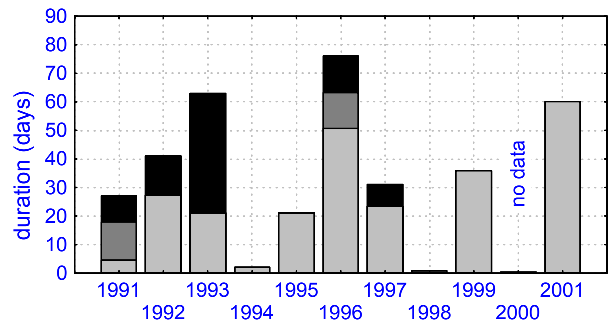


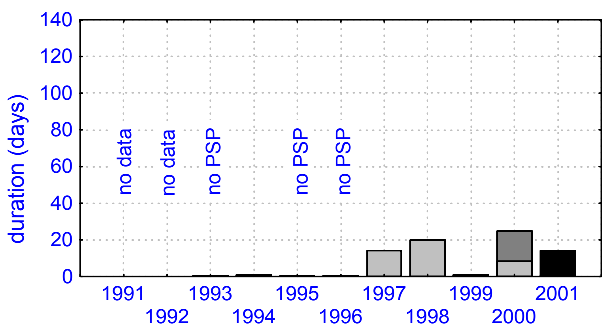
26. Southworth



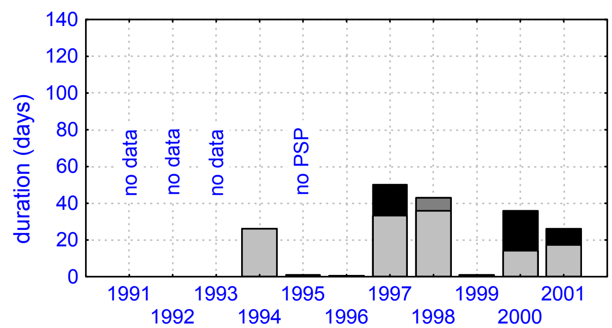
27. Quartermaster Harbor



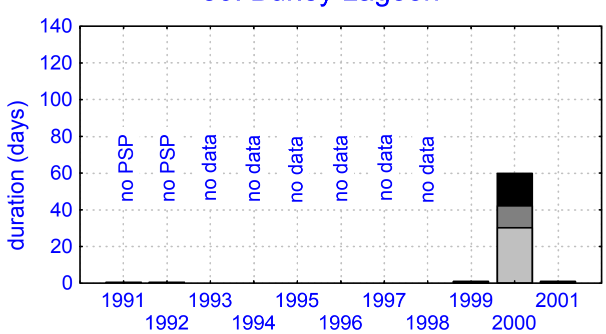
28. Steilacoom



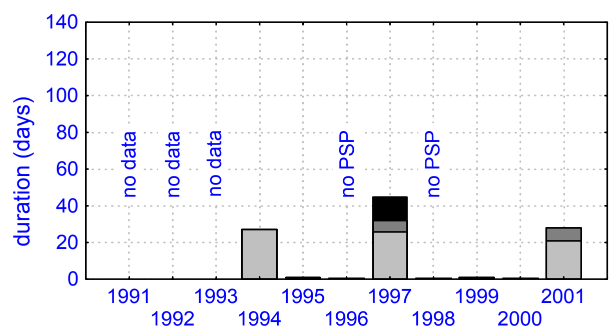
29. Filucy Bay



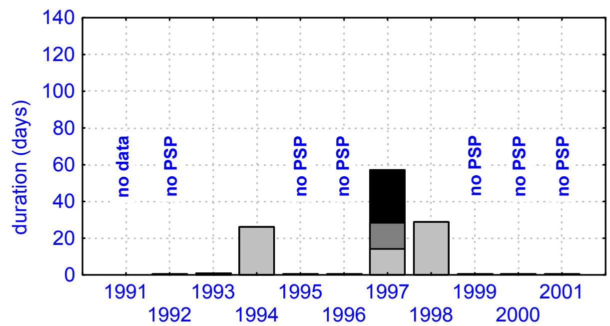
30. Burley Lagoon



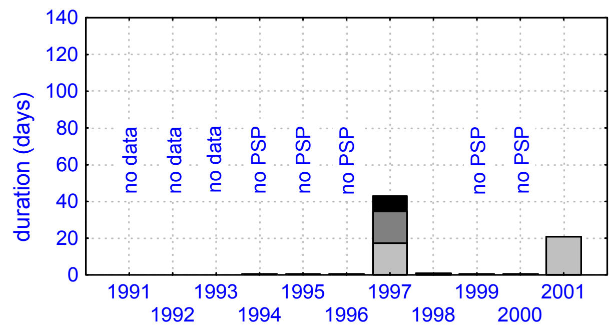
31. Johnson Point



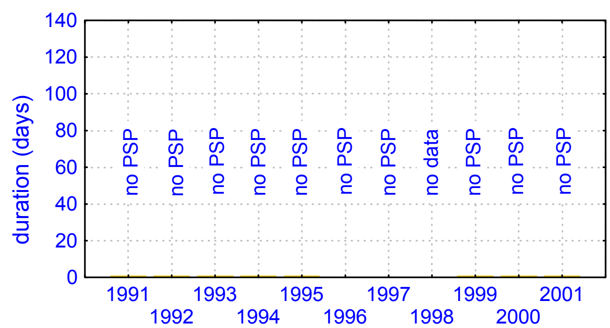
32. North Bay



33. Jarrell Cove



34. Totten Inlet



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